

### **REMARKS**

The specification has been amended to correct errors of a typographical and grammatical nature. Due to the large number of corrections thereto, applicants submit herewith a Substitute Specification, along with a marked-up copy of the original specification for the Examiner's convenience. Applicants submit that the substitute specification includes no new matter. Therefore, entry of the Substitute Specification is respectfully requested.

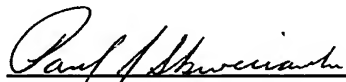
The abstract has also been amended to more correct errors of a grammatical nature.

Applicants also submit herewith, by separate letter, the certified copy of the priority document.

Entry of the preliminary amendments and examination of the application is respectfully requested.

To the extent necessary, applicant's petition for an extension of time under 37 CFR 1.136. Please charge any shortage in the fees due in connection with the filing of this paper, including extension of time fees, to Deposit Account No. 01-2135 (501.42964X00) and please credit any excess fees to such deposit account.

Respectfully submitted,



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## LIQUID CRYSTAL DISPLAY DEVICE

### BACKGROUND OF THE INVENTION

#### ~~1. FIELD OF THE INVENTION~~

The present invention relates to a liquid crystal display device, and more particularly, to a liquid crystal display device <sup>in</sup> which ~~can enhance~~ <sup>the</sup> a contrast of an image <sup>is enhanced</sup> by preventing the reflection of ~~an~~ external light.

#### ~~2. DESCRIPTION OF THE RELATED ART~~

A liquid crystal display device is used in a television receiver set, a personal computer, <sup>and as the</sup> a display <sup>device for</sup> a portable terminal or the like. Since the liquid crystal display device is light <sup>in</sup> weight ~~and~~ and exhibits a small power consumption, the liquid crystal display device is <sup>commonly</sup> used as <sup>a</sup> display <sup>device in</sup> ~~means of~~ a small electronic terminal, such as a mobile telephone or the like.

Further, since <sup>such a</sup> portable terminal is used <sup>of</sup> outside houses or buildings, a partial-transmissive-type liquid crystal display device is used. The partial-transmissive-type liquid crystal display device displays images by making use of ~~an~~ external light when <sup>the outside</sup> ~~a~~ environment is bright and displays images by making use of light from a backlight when the <sup>outside</sup> ~~using~~ environment is dark (see Japanese Unexamined Patent Publication 350158/2001, for example). Further, even with respect to a liquid crystal display device <sup>which employs</sup> ~~adopting~~ a full-transmissive-type panel, there <sup>is</sup> ~~exists~~ a liquid crystal display device which can

~~perform~~<sup>produce</sup> a transmissive display which mainly uses light from a backlight and a reflective display which reflects light incident from an image observing side on a reflector of the backlight (see Japanese Unexamined Patent Publication 98960/2002 (paragraphs 0034 to 0043, Fig. 2 and Fig. 3) and Japanese Unexamined Patent Publication 98963/2002 (paragraphs 0001 to 0007, 0016 to 0017, Fig. 1, Fig. 3, Fig. 5, for example). Further, in many liquid crystal display devices, thin film transistors are used as switching elements.

Recently, to cope with ~~the~~<sup>a</sup> demand for a liquid crystal display device having <sup>a</sup> higher definition, the number of pixels of the liquid crystal display device ~~is~~<sup>has been</sup> increased. ~~Along with~~<sup>As a result of</sup> the increase ~~of~~<sup>in</sup> the number of pixels, thin film transistors which exhibit a high operational speed are required. In ~~the~~<sup>a</sup> liquid crystal display device having high definition, as a semiconductor layer of the thin film transistor, polysilicon (polycrystalline silicon) is used in place of amorphous silicon. With the use of polysilicon as the material of the semiconductor layer, the operational speed of the thin film transistor is increased, whereby images of high definition can be displayed. <sup>P</sup> Further, there ~~has been~~<sup>is a</sup> known ~~a~~<sup>is a</sup> technique ~~which stacks~~<sup>in</sup> an upper-side background layer and a lower-side background layer ~~on~~<sup>as stacked</sup> a glass substrate, laser beams are radiated to semiconductor thin films formed on the upper-side background layer, and the semiconductor thin films are crystallized (see Japanese Unexamined Patent

Publication 132306/1994 (paragraphs 0002 to 0007, Fig. 1 to Fig. 4).

Usually, the thin film transistors are formed on the glass substrate and so-called alkali-free glass is used as a material of the glass substrate. This glass substrate includes impurities and the impurities intrude into the polysilicon film, so that the transistor characteristics of the thin film transistor formed on the substrate ~~is~~<sup>are</sup> degraded.

To suppress the intrusion of the impurities into the polysilicon film from the glass substrate, a background film made of silicon nitride, silicon oxide or the like is interposed between the glass substrate and the polysilicon film. The background film is formed over ~~a~~<sup>the</sup> whole surface of a panel and light-transmissive pixel electrodes are formed over the background film ~~besides~~<sup>in addition to</sup> the thin film transistors. However, when the background film and the pixel electrodes are stacked, this gives rise to reflection of external light ~~is~~ attributed to the difference in ~~the~~<sup>the</sup> refractive indices of ~~the~~<sup>the</sup> respective films.

In the conventional liquid crystal display device using ~~the~~<sup>a</sup> backlight, the background film is formed also in the light transmissive region. Accordingly, there has been a drawback ~~in~~ that, when the external light is reflected in the region where the light transmissive pixel electrodes are formed, ~~the~~<sup>the</sup> contrast of ~~the~~<sup>the</sup> images is lowered.

Further, in the partial-transmissive-type liquid crystal

display device, the light reflective region and the light transmissive region are <sup>with</sup> formed in one pixel. Accordingly, when the image is displayed by making use of light from the backlight, the transmitting light is blocked by the reflective region, and, hence, the luminance of the screen is low. By adopting the full-transmissive panel structure having no reflective electrode in the pixel electrode and by reflecting the external light by <sup>used</sup> the backlight, the luminance when the backlight is used can be enhanced. However, since such a display device is constituted by stacking the background film, the electrodes, <sup>the</sup> interlayer insulation films and the like, interface reflections attributed to the difference in refractive index occur on <sup>the</sup> interfaces of <sup>the</sup> respective films. Accordingly, with respect to the full-transmissive-type liquid crystal display device which reflects the external light by <sup>used</sup> the backlight, there has been a drawback <sup>in</sup> that, when the images are displayed by the reflected light, an inverted image whose tint is inverted is displayed.

#### SUMMARY OF THE INVENTION

<sup>In a</sup> <sup>aspect of the</sup>  
~~According to one~~ typical liquid crystal display device of the present invention, ~~the liquid crystal display device~~ <sup>in which there are</sup> includes thin film transistors and pixel electrodes formed on a substrate <sup>by the present invention</sup> and is characterized in that each thin film transistor includes a silicon film, a gate electrode, and a source electrode which is electrically connected to <sup>a</sup> ~~the~~ pixel electrode, <sup>disposed</sup> between

the silicon film and the substrate and between the pixel electrode and the substrate, a silicon oxide film and a silicon nitride film which is formed between the silicon oxide film and the substrate are interposed, and a film thickness of the silicon nitride film is larger than a film thickness of the silicon oxide film.

Here, the liquid crystal display device of the present invention is also characterized in that the silicon nitride film satisfies <sup>the</sup> ~~a~~ following formula, assuming <sup>that</sup> ~~the~~ film thickness <sup>is</sup> ~~as~~  $d(\text{nm})$  and <sup>the</sup> ~~a~~ refractive index <sup>for</sup> ~~when~~ a wavelength <sup>of</sup> ~~is~~  $555\text{nm}$  <sup>is</sup> ~~as~~  $n$  ( $m$  being an arbitrary integer).

$$d - 10 \leq 555 \times m / (2 \times n) \leq d + 10$$

Further, the liquid crystal display device of the present invention is also characterized in that the silicon nitride film satisfies <sup>the</sup> ~~a~~ following formula, assuming <sup>that</sup> ~~the~~ film thickness <sup>is</sup> ~~as~~  $d(\text{nm})$  and <sup>the</sup> ~~a~~ refractive index <sup>for</sup> ~~when~~ a wavelength <sup>of</sup> ~~is~~  $555\text{nm}$  <sup>is</sup> ~~as~~  $n$  ( $m$  being an arbitrary integer).

$$0.9d \leq 555 \times m / (2 \times n) \leq 1.1d$$

Further, the liquid crystal display device of the present invention is also characterized in that the film thickness of the silicon nitride film falls within a range of 130nm to 160nm.

Alternatively, the film thickness of the silicon nitride film falls within a range of 126nm to 165nm.

Further, according to another typical <sup>aspect of the</sup> liquid crystal display device of the present invention, thin film transistors

and light transmissive pixel electrodes are formed over a substrate, the thin film transistors <sup>are</sup> ~~is~~ constituted of a polysilicon film, a gate electrode, a drain electrode and a source electrode, the substrate includes a background film, the polysilicon film and the light transmissive pixel electrode are arranged over the background film, the background film is constituted of a substrate-side silicon nitride film and a liquid-crystal-layer-side silicon oxide film, and the silicon nitride film is thicker than the silicon oxide film.

Here, the silicon nitride film satisfies <sup>the</sup> ~~a~~ following formula, assuming <sup>that the</sup> ~~a~~ film thickness thereof <sup>is</sup> ~~as~~  $d(\text{nm})$  and <sup>the</sup> ~~a~~ refractive index <sup>for</sup> ~~where~~  $n$  a wavelength thereof <sup>is</sup> ~~is~~  $555\text{nm}$  ~~as~~  $n$ .

$$d - 10 \leq 555 \times m / (2 \times n) \leq d + 10$$

Further, between the substrate-side silicon nitride film and the light transmissive pixel electrode, a silicon oxide film and a second silicon nitride film are sequentially stacked. The interlayer insulation film between the silicon oxide film and the second silicon nitride film respectively satisfy <sup>the</sup> ~~a~~ following formula, assuming <sup>that the</sup> ~~a~~ film thickness thereof <sup>is</sup> ~~as~~  $d(\text{nm})$  and <sup>the</sup> ~~a~~ refractive index thereof <sup>for</sup> ~~where~~  $n$  a wavelength thereof <sup>is</sup> ~~is~~  $555\text{nm}$  ~~as~~  $n$  ( $m$  being an arbitrary integer).

$$d - 10 \leq 555 \times m / (2 \times n) \leq d + 10$$

Further, the silicon oxide film arranged between the substrate-side silicon nitride film and the light transmissive pixel electrode is constituted of a liquid-crystal-side

background film, a gate insulation film and an interlayer insulation film, and the second silicon nitride film is an interlayer insulation film.

Another constitution of the liquid crystal display device of the present invention is characterized in that ~~one~~ <sup>the</sup> of two substrates which face each other with a liquid crystal layer <sup>disposed</sup> therebetween, one substrate includes thin film transistors, and the thin film transistors <sup>are</sup> constituted of a semiconductor layer, a gate electrode which is connected to a ~~gate~~ <sup>gate</sup> line, a drain electrode which is connected to a drain line and a source electrode which is connected to a pixel electrode. Further, in a region <sup>defined</sup> ~~surrounded~~ by two neighboring gate lines and two neighboring drain lines, <sup>there is</sup> a reflective region, which is provided with a reflective electrode which reflects ~~an~~ <sup>that</sup> external light, ~~which~~ passes through <sup>the</sup> liquid crystal layer <sup>and which is</sup> connected to the source electrode, and a transmissive region which is provided with a light transmissive pixel electrode <sup>that</sup> ~~which~~ is connected to the source electrode and allows light from a backlight to pass therethrough ~~are formed~~ <sup>the</sup>, wherein ~~a~~ <sup>the</sup> thickness of the liquid crystal layer differs between the reflective region and the transmissive region. Further, a first film and a second film are formed between the light transmissive pixel electrode of the transmissive region and the substrate, <sup>such that</sup> the refractive index differs between the first film and the second film, and the first film and the second film respectively satisfy <sup>the</sup> a following formula,



that the  
assuming ~~a~~ film thickness thereof <sup>is</sup> ~~is~~ d(nm) and <sup>the</sup> ~~a~~ refractive index <sup>for</sup> ~~when~~ a wavelength <sup>of</sup> ~~is~~ 555nm <sup>is</sup> ~~as~~ n (m being an arbitrary integer).

$$d - 10 \leq 555 \times m / (2 \times n) \leq d + 10$$

Here, the liquid crystal display device of the present invention is also characterized in that the first film is made of silicon nitride and the second film is made of silicon oxide.

Further, the liquid crystal display device of the present invention is also characterized in that a third film made of silicon nitride is formed on a second film and the third film satisfies a following formula, assuming a film thickness thereof as d(nm) and a refractive index when a wavelength is 555nm as n (m being an arbitrary integer).

$$d - 10 \leq 555 \times m / (2 \times n) \leq d + 10$$

Further, another liquid crystal display device of the present invention is provided in the form of ~~directed to~~ a full transmissive type liquid crystal display device, which includes a liquid crystal panel in which two substrates face each other in an opposed manner with a liquid crystal layer <sup>disposed</sup> therebetween, and a backlight which is formed on one surface side of the liquid crystal panel, wherein one substrate includes a background film, thin film transistors and light transmissive pixel electrodes ~~are~~ formed over the background film, and the thin film transistor includes a polysilicon film, a gate electrode, a drain electrode and a source electrode. Here, the background film includes a substrate-side silicon nitride film and a liquid-crystal-layer-side silicon

oxide film, and the silicon nitride film is formed <sup>to be</sup> thicker than silicon oxide film. Further, the silicon nitride film satisfies <sup>the</sup> a following formula, assuming <sup>that the</sup> a film thickness thereof <sup>is</sup>  $d$  (nm) and <sup>the</sup> a refractive index <sup>for</sup> a wavelength <sup>of</sup>  $555\text{nm}$  <sup>is</sup>  $n$  ( $m$  being an arbitrary integer).

$$0.9d \leq 555 \times m / (2 \times n) \leq 1.1d$$

Further, between the background film and the pixel electrode, a silicon oxide film and a second silicon nitride film are sequentially stacked, and the silicon oxide film and the second silicon nitride film satisfy <sup>the</sup> a following formula, assuming <sup>that the</sup> a film thickness thereof <sup>is</sup>  $d$  (nm) and <sup>the</sup> a refractive index <sup>for</sup> a wavelength <sup>of</sup>  $555\text{nm}$  <sup>is</sup>  $n$  ( $m$  being an arbitrary integer).

$$0.9d \leq 555 \times m / (2 \times n) \leq 1.1d$$

Further, in addition to the above-mentioned constitutions, common electrodes are formed on the same substrate on which the pixel electrodes are formed or the common electrodes are formed <sup>the other</sup> on another ~~one~~ substrate.

According to the present invention, it is possible to <sup>provide an enhanced</sup> provide a display device which can ~~enhance~~ contrast and thereby, can enhance the visibility of images.

#### BRIEF DESCRIPTION OF THE DRAWINGS

<sup>disymmetric</sup> Fig. 1 is a plan view of a pixel portion of a liquid crystal display device of the present invention.

Fig. 2 is a cross-sectional view taken along a line I-I

in Fig. 1.

Fig. 3 is a cross-sectional view taken along a line II-II in Fig. 1.

Fig. 4 is a ~~view~~<sup>table</sup> showing ~~a~~<sup>examples of the</sup> material and ~~a~~<sup>the</sup> thickness of films or layers and refractive indices when ~~a~~<sup>the</sup> wavelength is 555nm.

Fig. 5 is a graph showing a spectral luminous reflectance when ~~a~~<sup>the</sup> thickness of a first background film is changed from 50nm to 180nm.

Fig. 6 is a graph showing the relationship between ~~a~~<sup>the</sup> wavelength of light and the spectral luminous reflectance when ~~a~~<sup>the</sup> thickness of the first background film shown in Fig. 5 is 50nm.

Fig. 7 a graph showing the relationship between ~~a~~<sup>the</sup> wavelength of light and the spectral luminous reflectance when ~~a~~<sup>the</sup> thickness of the first background film shown in Fig. 5 is 140nm.

Fig. 8 is a view showing the constitution of films of a partial transmissive type liquid crystal display device for ~~a~~<sup>a</sup> normally black display.

Fig. 9 is a perspective view with a part broken away of a liquid crystal display device to which the present invention is applied.

Fig. 10 is a ~~plan~~<sup>diagrammatic</sup> view of a pixel portion of a liquid crystal display device ~~of the~~<sup>representing a</sup> second embodiment of the present invention.

Fig. 11 is a cross-sectional view taken along a line I-I in Fig. 10.

Fig. 12 is a cross-sectional view taken along a line II-II

in Fig. 10.

Fig. 13 is a ~~view~~<sup>table</sup> showing ~~a~~<sup>the</sup> material and ~~a~~<sup>the</sup> thickness of films or layers and refractive indices when ~~a~~<sup>the</sup> wavelength is 555nm.

Fig. 14 is a graph showing a spectral luminous reflectance when ~~a~~<sup>the</sup> thickness of a second interlayer insulation film is changed from 100nm to 500nm.

Fig. 15 is a graph showing a spectral luminous reflectance when ~~a~~<sup>the</sup> thickness of the first background film is changed from 25nm to 350nm.

Fig. 16 is a graph showing a spectral luminous reflectance when ~~a~~<sup>the</sup> thickness of the ITO is changed from 50nm to 300nm.

Fig. 17 is a graph showing a spectral luminous reflectance when ~~a~~<sup>the</sup> thickness of the second interlayer insulation film is changed from 100nm to 400nm.

Fig. 18 is a graph showing a spectral luminous reflectance when ~~a~~<sup>the</sup> thickness of the first background film is changed from 50nm to 325nm.

Fig. 19 is a graph showing the relationship between ~~a~~<sup>the</sup> wavelength of light and ~~a~~<sup>the</sup> spectral luminous reflectance when ~~a~~<sup>the</sup> thickness of the first background film is 75nm.

Fig. 20 is a graph showing the relationship between ~~a~~<sup>the</sup> wavelength of light and ~~a~~<sup>the</sup> spectral luminous reflectance when ~~a~~<sup>the</sup> thickness of the first background film is 150nm.

Fig. 21 is a ~~plan~~<sup>diagrammatic</sup> view showing ~~a~~<sup>the</sup> structure when a second substrate on which color filters are formed is overlapped ~~to~~<sup>with</sup> A

a first substrate.

Fig. 22 is a <sup>diagrammatic</sup> plan view showing a pixel region of <sup>a</sup> ~~the~~ liquid crystal display device <sup>representing a</sup> ~~of the~~ third embodiment of the present invention.

Fig. 23 is a <sup>diagrammatic</sup> plan view of black matrixes BM formed on the second substrate.

Fig. 24 is a cross-sectional view taken along a line III-III in Fig. 22.

Fig. 25 is a cross-sectional view of the liquid crystal display device <sup>is shown</sup> ~~for explaining~~ the arrangement of a backlight structural body.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the present invention <sup>will be</sup> ~~are~~ explained hereinafter in conjunction with <sup>the</sup> ~~attached~~ drawings.

Fig. 1 is a plan view showing a pixel portion of a liquid crystal display device <sup>representing a</sup> ~~of the~~ first embodiment of the present invention.

<sup>In a typical liquid crystal display device,</sup> ~~Out of~~ two substrates <sup>disposed</sup> ~~which~~ are arranged to face each other with a liquid crystal layer <sup>and</sup> ~~therebetween~~, thin film transistors

are formed on one substrate. Further, on each region which is <sup>defined</sup> ~~surrounded~~ by a <sup>pair</sup> ~~group~~ of <sup>adjacent</sup> ~~gate~~ lines and a <sup>pair</sup> ~~group~~ of <sup>adjacent</sup> ~~drain~~ lines

— which cross each other, a switching element, which is turned on  
— in response to a scanning signal from the gate line, and a pixel  
— electrode, to which a video signal is supplied from the drain

line through the switching element, are formed, thus constituting a so-called pixel. The region which is ~~surrounded~~<sup>defined</sup> by the ~~group~~<sup>pair</sup> of ~~gate~~<sup>adjacent</sup> lines and the ~~group~~<sup>pair</sup> of ~~drain~~<sup>adjacent</sup> lines constitutes a pixel region. The thin film transistor is used as a switching element.

~~The~~<sup>illustrated in Fig. 1</sup> pixel is formed in the region surrounded by two neighboring gate lines 1 and two neighboring drain lines 2. A color image can be displayed on a front surface of a panel using <sup>an array of</sup> ~~these~~ three types of pixels (pixel for red, pixel for green, pixel for blue).

Within one pixel, <sup>there is</sup> a light reflective region, in which a reflective electrode 3 is formed, and a light transmissive region 4, on which a reflective electrode is not formed. ~~are provided.~~ The light transmissive region 4 is formed by <sup>providing</sup> ~~forming~~ an opening in the reflective electrode 3. A transparent electrode 7 is formed in the light transmissive region 4. The pixel electrode is constituted of the reflective electrode 3 and the transparent electrode 7.

Below the reflective electrode 3, the gate line (gate electrode) 1, the drain line (drain electrode) 2, a polysilicon film 5, a storage line (storage electrode) 6 and the transparent electrode 7 are formed.

Fig. 2 is a cross-sectional view taken along a line I-I in Fig. 1.

A first background film 9 is formed on the substrate 8 on which the thin film transistors are formed, and a second

background film 10 is formed on the first background film 9. Then, the polysilicon film 5 is formed on the second background film 10.

The polysilicon film 5 can be formed using either ~~ex~~ solid-phase crystallization or a laser annealing method. Since ~~the~~ solid-phase crystallization heats the whole substrate at a high temperature, it is necessary to use a material which exhibits high resistance against heat, such as quartz glass. On the other hand, in the laser annealing method, an amorphous silicon layer is formed on a glass substrate by annealing using laser beams. Accordingly, it is unnecessary to heat the whole substrate ~~at~~<sup>to</sup> a high temperature. The polysilicon film which can be formed at a low temperature, ~~that obtained with~~<sup>use of</sup> compared to, the solid-phase crystallization, is formed on a glass substrate, which is referred to as alkali-free glass. This glass substrate includes impurities. To prevent the impurities from intruding into the polysilicon film, a background film is formed on the glass substrate.

In forming the polysilicon film, by crystallizing polysilicon on a silicon oxide film, it is possible to form ~~the~~<sup>a</sup> polysilicon layer having small grain boundaries. However, to suppress the intrusion of the impurities into the silicon oxide film from the glass substrate, it is necessary to increase ~~the~~<sup>the</sup> thickness of the silicon oxide film.

In view of the above, a silicon nitride film is used as

the first background film 9. Although <sup>a</sup>~~the~~ silicon nitride film is not favorable for the formation of the polysilicon film 5, the silicon nitride film can suppress the intrusion of ~~the~~ impurities into the polysilicon film from the glass substrate 8. Accordingly, it is possible to suppress the degradation of transistor characteristics attributed to the diffusion of sodium or the like from the glass substrate.

A silicon oxide film is formed as the second background film 10. By forming the polysilicon film 5 on the oxide silicon film, it is possible to form crystallized silicon having a large particle size. Further, due to the formation of the oxide film, it is possible to prevent ~~the~~ fluctuation of <sup>the</sup>~~s~~ threshold voltage of the transistor.

By forming <sup>a</sup>~~the~~ silicon nitride film as the first background film 9 and by forming <sup>a</sup>~~the~~ silicon oxide film as the second background film 10, it is possible to form the thin background film as a whole. <sup>With a</sup> thinner ~~the~~ background film, it is possible to form the background film with <sup>only a</sup> small undulation or waving, and, <sup>any changes in the</sup> hence, it is possible to reduce ~~the change of~~ film thickness.

A gate insulation film 12 is formed such that the film 12 covers the polysilicon film 5. Gate electrodes 1 are formed on the gate insulation film 12. The gate insulation film 12 is arranged to provide an insulation between the polysilicon film 5 and the gate electrodes 1. In this embodiment, the gate insulation film 12 is formed of a silicon oxide film and the



gate electrode 1 is made of a molybdenum tungsten alloy.

Over the gate insulation film 12, a first interlayer insulation film 13 is formed such that the film 13 covers the gate lines 1. The first interlayer insulation film 13 is formed of a silicon oxide film and is mainly <sup>used</sup> ~~served~~ for ~~ensuring the~~ insulation between the gate electrodes 1 and the drain electrodes 2 or the source electrodes 14.

Contact holes 15 are formed in the gate insulation film 12 and the first interlayer insulation film 13. Here, the drain electrodes 2 and the semiconductor layers 5 are connected to each other via the contact holes 15, while the source electrodes 14 and the semiconductor layers 5 are also connected to each other via the contact holes 15. In this embodiment, the drain electrode 2 and the source electrode 14 have <sup>a</sup> ~~the~~ three-layered structure consisting of an upper layer made of titanium, an intermediate layer made of aluminum and a lower layer made of titanium (titanium/aluminum/titanium). By arranging the titanium layer at the upper layer and the lower layer, the electric connection between the polysilicon film 5 and the transparent electrode (ITO) 7 is ensured.

Over the first interlayer insulation film 13, a second interlayer insulation film 16 is formed such that the film 16 covers the drain electrodes 2 and the source electrodes <sup>14</sup> ~~14~~. The second interlayer insulation film 16 is formed of a silicon nitride film. With the use of <sup>a</sup> ~~the~~ silicon nitride film as the

second interlayer insulation film 16, it is possible to prevent the intrusion of the contaminating matter# into the thin film transistor from an organic insulation film 18, and, at the same time, it is possible to enhance the adhesiveness between the organic insulation film 18 and the second interlayer insulation film.

Over the second interlayer insulation film 16, the transparent electrodes 7 are formed. Contact holes 15 are formed in the second interlayer insulation film 16 so as to establish ~~the electric~~ <sup>an electric</sup> connection between the source electrodes 14 and the transparent electrodes 7. The transparent electrodes 7 are made of ITO (Indium Tin Oxide).

Over the second interlayer insulation film 16, a third interlayer insulation film 18 is formed such that the film 18 partially covers the transparent electrodes 7. The third interlayer insulation film 18 is made of an organic material (an organic insulation film). By arranging the organic insulation film 18 over the second interlayer insulation film 16, it is possible to reduce the coupling capacitance between wiring, such as the gate lines, or between the drain lines. Due to <sup>a</sup> ~~the~~ reduction of <sup>the</sup> ~~the~~ coupling capacitance, it is possible to reduce the power consumption of the liquid crystal display device.

Over the third interlayer insulation film 18, the reflective electrodes 3 are formed. The reflective electrode 3 has a two-layered structure (titanium-tungsten

alloy/aluminum) consisting of an upper layer made of a titanium-tungsten alloy and a lower layer made of aluminum. The titanium-tungsten alloy ensures <sup>an electrical</sup> ~~the electrical~~ connection between the reflective electrode 3 and the transparent electrode 7.

Fig. 3 is a cross-sectional view taken along a line II-II in Fig. 1.

A region on which the reflective electrode 3 is formed constitutes a reflective region AR, and a region on which the reflective electrode 3 is not formed constitutes a transmissive region TA.

The first background film 9 and the second background film 10 are formed on the glass substrate 8. These background films are formed over the whole pixel region. When the background films are removed <sup>during the course</sup> ~~in the midst~~ of the <sup>forming</sup> ~~manufacturing~~ step of the low-temperature silicon, in the succeeding photolithography step, a developing solution, an etchant, a resist removing liquid or the like is directly brought into contact with the glass substrate. Accordingly, ions, such as sodium ions or the like, in the glass substrate <sup>are</sup> ~~is~~ dissolved.

Due to the provision of the background films, the developing solution, the etchant, the resist removing liquid or the like is not brought into contact with the glass substrate in the photolithography step, and hence, it is possible to reuse these liquids again after filtering them, whereby it is possible to prevent the whole manufacturing line from <sup>being subjected to</sup> ~~contamination~~.

Further, the manufacturing cost can be reduced.

The polysilicon film 5 is formed over the second insulation background film and the first interlayer insulation film 13 is formed over the second background film such that the insulation film 13 covers the polysilicon film 5. Over the first interlayer insulation film, storage electrodes 6 are formed. The storage electrode 6 faces the source electrode 14 and the transparent electrode 7 by way of the insulation film in an opposed manner, thus forming a holding capacitance.

Further, since the storage electrode 6 is formed within the reflective region RA, it is unnecessary to allow light to pass therethrough. Accordingly, the storage electrode 6 is formed of a molybdenum-tungsten film.

The third interlayer insulation film 18 includes an opening ~~portion~~ at a portion thereof. As shown in Fig. 1, the reflective electrode 3 forms an opening ~~portion~~ 4 by tracing the opening formed in the third interlayer insulation film 18. The reflective electrode 3 includes a connection portion 11 in the opening ~~portion~~ <sup>of</sup> the third interlayer insulation film 18. The reflective electrode 3 is electrically connected with the transparent electrode 7 through the connecting portion 11.

Further, an inclined portion 17 having an angle  $\theta$  is formed <sup>between the reflective electrode 3</sup> ~~between~~ the third interlayer insulation film 18 and the transparent electrode 7. The angle  $\theta$  is smaller than 90 degrees and is about 45 degrees. By forming such an inclined portion

17, rubbing mottling on the orientation film can be reduced.

The transparent electrode 7 is formed in an area <sup>that is</sup> wider than the opening ~~portion~~ 4 formed in the reflective electrode 3. A backlight (not shown in the drawing) is arranged below the glass substrate, and the transparent electrode 7 constitutes a light transmissive pixel electrode which allows light from the backlight to pass therethrough.

The pixel portion faces the counter substrate 21, <sup>that is</sup> provided with the counter electrodes 20, with the liquid crystal layer <sup>being disposed</sup> 19 therebetween. Further, <sup>the</sup> thickness (a gap) of the liquid crystal layer differs between <sup>the</sup> gap L1 of the reflective region and <sup>the</sup> gap L2 of <sup>the</sup> transmissive region. That is, the thickness of the liquid crystal layer differs between the reflective region and the transmissive region.

In this embodiment, the above-mentioned constitution is applied to a liquid crystal display device for normally black display.

The liquid crystal display device for normally black display exhibits <sup>a</sup> higher transmissivity than <sup>a</sup> liquid crystal display device for normally white display, and hence, the liquid crystal display device can use thick color filters, <sup>providing a</sup> whereby the liquid crystal display device <sup>that produces</sup> is excellent in color reproducibility.

Further, by setting the gap L2 of the transparent region <sup>so that it is</sup> larger than the gap L1 of the reflective region, the luminance

can be enhanced.

In the transmissive region, light transmissive films are stacked, and these stacked films differ in ~~the~~ refractive index from each other. The thicknesses of the light transmissive films are controlled to prevent the reflection of ~~an~~ external light from the counter substrate side.

In the transmissive region, between the transparent electrode 7 and the glass substrate 8, the first background film 9, the second background film 10, the gate insulation film 12 and the first interlayer insulation film 13 are arranged.

These films are respectively configured to satisfy ~~a~~ the following formula, assuming the film thickness ~~is~~ <sup>is</sup>  $d$ (nm) and ~~a~~ <sup>the</sup> refractive index ~~when~~ <sup>for</sup> a wavelength ~~is~~ <sup>of</sup> 555nm ~~as~~ <sup>is</sup>  $n$  ( $m$  being an arbitrary integer excluding a negative integer).

$$d - 10 \leq 555 \times m / (2 \times n) \leq d + 10$$

Due to such a constitution, the reflection of the external light in the transmissive region can be suppressed whereby it is possible to provide ~~the~~ <sup>a</sup> liquid crystal display device <sup>in</sup> which ~~can enhance the contrast~~ <sup>is enhanced</sup>.

Fig. 4 shows a specific ~~embodiment~~ <sup>example</sup> of materials, thicknesses (film thicknesses) of respective films or layers and the refractive indices when the wavelength is 555nm. In this embodiment, the gap L2 of the transmissive region is set to 5.2 $\mu$ m and the gap L1 of the reflective region is set to 3.7 $\mu$ m.

The first background film and the second background film

differ in the refractive index<sup>stand</sup>. To protect the polysilicon film from the impurities in the glass substrate, the first background film may preferably have a film thickness of at least 45nm. In this embodiment, the material of the first background film 9 is silicon nitride, the refractive index of the first background film 9 is 2.0, and the film thickness of the first background film 9 is 130nm to 150nm. The material of the second background film 10 is silicon oxide, the refractive index of the second background film 10 is 1.5, and the film thickness of the second background film 10 is 100nm. The first background film is formed <sup>so as to be</sup> thicker than the second background film.

The material of the gate insulation film 12 is silicon oxide in the same manner as the second background film, while the refractive index of the gate insulation film 12 is 2.0 and the film thickness of the gate insulation film 12 is 100nm. The material of the first interlayer insulation film 13 is silicon oxide in the same manner as the second background film, while the refractive index of the first interlayer insulation film 13 is 2.0 and the film thickness of the first interlayer insulation film 13 is 540nm. With respect to the second interlayer insulation film 16, the material is silicon nitride, the refractive index is 2.0 and the film thickness is 200nm. With respect to the transparent electrode, the material is ITO, the refractive index is 2.0 and the film thickness is 77nm. Further, the refractive indices of the orientation film 22 and the liquid

crystal are 1.5.

Among these films, the second background film, which constitutes the liquid-crystal-layer-side background film, has the same refractive index as that of the gate insulation film and the first interlayer insulation film, and, hence, they can be considered as the same films. Further, since the second interlayer insulation film and the transparent electrode have the same refractive index, these films are also considered to be the same film. Accordingly, the first film is the silicon nitride film, which is constituted of the first background film, and, hence, the refractive index is 2.0 and the film thickness is 130 to 150nm. The second film is the silicon oxide film, which is constituted of the second background film, the gate insulation film and the first interlayer insulation film, and, hence, the refractive index is 1.5 and the film thickness is 740nm. Further, the third film has <sup>a</sup>the refractive index of 2.0 and <sup>a</sup>the film thickness of 277nm.

The above-mentioned films satisfy <sup>the</sup> following formula, assuming <sup>that</sup> the film thickness <sup>is</sup>  $d$  (nm) and <sup>the</sup> refractive index <sup>when</sup>  $n$  a wavelength <sup>of</sup>  $555\text{nm}$  <sup>is</sup>  $m$  ( $m$  being an arbitrary integer excluding negative integer).

$$d - 10 \leq 555 \times m / (2 \times n) \leq d + 10$$

Due to such a constitution, the reflection of the external light in the transmissive region can be suppressed, whereby it is possible to provide <sup>a</sup>the liquid crystal display device <sup>with</sup> which



~~can enhance~~ the contrast. <sup>is enhanced</sup>

It is more preferable to set the thickness of the first background film to 140nm.

Fig. 5 is a ~~view~~ <sup>graph</sup> showing the spectral luminous reflectance when the second background film, the gate insulation film, the first interlayer insulation film and the second interlayer insulation film assume <sup>the</sup> values shown in Fig. 4, and the film thickness of the first background film is changed within a range of 50nm to 180nm. Fig. 6 is a ~~view~~ <sup>graph</sup> showing the relationship between the wavelength of light and the spectral luminous reflectance when the film thickness of the first background film in Fig. 5 is 50nm. Fig. 7 is a ~~view~~ <sup>graph</sup> showing the relationship between the wavelength of light and the spectral luminous reflectance when the film thickness of the first background film in Fig. 5 is 140nm.

As can be clearly understood from Fig. 5, Fig. 6 and Fig. 7, the spectral luminous reflectance takes the minimum value when the film thickness of the background film is set to 140nm.

This value agrees with a following equation, wherein the film thickness is  $d$ (nm) and <sup>the</sup> refractive index <sup>for</sup> ~~when~~ a wavelength <sup>of</sup> 555nm is  $n$ .

$$d = 555 \times m / 2 \times n$$

<sup>a</sup> ~~human~~ <sup>human</sup> is most sensitive to light having the wavelength of 555nm, and, hence, the contrast can be enhanced by suppressing the reflection of light having <sup>a</sup> ~~the~~ wavelength in the vicinity

of 555nm.

It is necessary to adjust the film thickness by adding about 10% of film thickness to the calculated value or subtracting about 10% of film thickness from the calculated value by considering manufacturing errors. The film thickness is preferably controlled to a value having an error <sup>d</sup>10nm.

Fig. 8 is view showing the film constitution of <sup>a</sup>the partial transmissive type liquid crystal display device <sup>producing a</sup>for normally black display.

The thickness of the liquid crystal layer in the transmissive region is set, by taking the polarizer and the optical retardation plate into consideration, to a value such that the optimum transmissive optical characteristics, such as contrast and transmissivity, can be obtained with respect to the transmitting light which passes <sup>through</sup> the liquid crystal layer once. Further, the thickness of the liquid crystal layer in the reflective region is set, by taking the polarizer and the optical retardation plate into consideration, to a value such that the optimum transmissive optical characteristics, such as contrast and transmissivity, can be obtained with respect to the reflecting light which passes <sup>through</sup> the liquid crystal layer twice. Accordingly, when light which passes <sup>through</sup> the liquid crystal layer, the reflective electrode and the liquid crystal layer in this order is blocked by the optical retardation plate and the polarizer, so that <sup>a</sup>the black display is <sup>produced</sup>~~performed~~, the reflective light <sup>a</sup>from the

transmissive region <sup>will</sup> differ in the thickness of the liquid crystal layer through which <sup>the</sup> light <sup>passes,</sup> and, hence, the light <sup>is</sup> differs <sup>is</sup> in retardation of the liquid crystal layer, whereby the light <sup>is</sup> ~~are~~ in a polarized state in which the optical retardation plate and the polarizer cannot block the light.

That is, when there is no difference between the gap L2 of the transmissive region and the gap L1 of the reflective region, the retardation <sup>caused by</sup> ~~of~~ the liquid crystal <sup>material</sup> is equal between the transmissive region and the reflective region, and, hence, the light <sup>is</sup> ~~are~~ blocked by the optical retardation plate and the polarizer. However, when there <sup>is a</sup> ~~exists the~~ difference between the gap L2 of the transmissive region and the gap L1 of the reflective region, the retardation <sup>caused by</sup> ~~of~~ the liquid crystal <sup>material</sup> differs between the transmissive region and the reflective region, and, hence, the reflective light from the transmissive region cannot be blocked.

Fig. 9 is a perspective view, with a part broken away, of a liquid crystal display device 24 to which the present invention is applied. The liquid crystal display device 24 is constituted by ~~incorporating~~ a counter substrate 21 having <sup>an</sup> image display screen, a glass substrate 8, which is arranged to face the counter substrate 21 with a liquid crystal layer <sup>disposed</sup> therebetween, and a backlight assembly 23, which is arranged on a back surface of the glass substrate 8 in a frame 25.

<sup>In accordance with the</sup> ~~The~~ present invention <sup>it is possible to</sup> ~~can~~ suppress the reflection of the

external light in the transmissive region, and hence, <sup>it is possible to</sup> ~~the present~~ <sup>a</sup> invention can enhance the contrast particularly in ~~the~~ liquid crystal display device <sup>in which there is a</sup> ~~having the~~ difference between the gap L2 of the transmissive region and the gap L1 of the reflective region.

The reflective light from the multilayered film is generated such that, since the refractive indices of the respective layers which constitute the multilayered film are different from each other, interface reflections occur between respective layers, and these interface reflections interfere with each other, thus generating the reflection light.

In the low-temperature polysilicon thin film transistor, the silicon oxide film, the silicon nitride film, the organic interlayer insulation film and ITO film are used. Among these films, by setting the optical thickness  $nd$  ( $n$ : refractive index,  $d$ : film thickness) to  $555/2$  (nm) with respect to ~~the~~ <sup>a</sup> film having the large refractive index, when the <sup>incident</sup> ~~light~~ <sup>has a</sup> ~~having~~ wavelength <sup>in the range</sup> ~~of~~ green which exhibits the highest visibility ~~is incident~~, the

phase of the reflective light becomes opposite from each other, and hence <sup>they</sup> ~~are~~ are offset from each other at both interfaces of the film having the large refractive index, whereby the reflectance becomes small.

Further, by setting the film thickness of the silicon nitride <sup>film</sup> which is used as the background film, to the above-mentioned value, as in the case of the previous embodiment,

while holding the film thicknesses of the gate insulation film, the interlayer insulation film and the transparent electrode to film thicknesses <sup>that are</sup> most suitable for the electrical <sup>characteristics</sup> of the low-temperature polysilicon transistor and holding capacitances, the interface reflection can be reduced.

Fig. 10 ~~is a view for explaining the second embodiment of the present invention and is a plan view of a pixel portion~~ <sup>according to a second embodiment of the present invention</sup> of a liquid crystal display device. Further, the embodiment shown in Fig. 10 is applicable to <sup>a</sup> ~~the~~ full transmissive type display device, which is not provided with reflective electrodes for displaying images by reflecting an external light to the pixel portion.

<sup>In this display device,</sup> ~~On~~ <sup>of</sup> two substrates ~~which~~ <sup>disposed</sup> are arranged to face each other with a liquid crystal layer <sup>and</sup> therebetween, thin film transistors are formed on one substrate (first substrate). Further, color filters are formed on <sup>the other</sup> ~~another~~ substrate (second substrate) ~~explained later~~.

On each region which is <sup>defined</sup> ~~surrounded~~ by a <sup>pair</sup> ~~group~~ of gate lines 1 and a <sup>pair</sup> ~~group~~ of drain lines 2 which cross each other, a switching element, which is turned on in response to a scanning signal from the gate line 1, and a pixel electrode 3, to which a video signal is supplied from the drain line 2 through the switching element, are formed. The region which is <sup>defined</sup> ~~surrounded~~ by the <sup>pair</sup> ~~group~~ of gate lines and the <sup>pair</sup> ~~group~~ of drain lines constitutes a pixel region.

The thin film transistor (TFT) is used as a switching element. The thin film transistor is constituted of a gate electrode G, which is connected to the gate line 1, a polycrystalline silicon film 5, a drain electrode D, which is connected to the drain line 2, and a source electrode S, which is connected to the pixel electrode.

Each pixel is formed in a defined region, ~~surrounded~~ by two neighboring gate lines 1 and two neighboring drain lines 2. A color image can be displayed on a front surface of a panel using an array of ~~these~~ three types of pixels (pixel for red, pixel for green, pixel for blue).

Within one pixel, a common electrode C and a pixel electrode 3 are formed. Further, the common electrode C and the pixel electrode 3 are formed on the same substrate, thus constituting a liquid crystal display device adopting a so-called lateral electric field (In-Plane-Switching) mode of operation ~~system~~. By arranging a common line 6, which is connected to the common electrode C, in parallel and above the gate line 1, the pixel is enlarged.

Fig. 11 is a cross-sectional view taken along a line I-I in Fig. 10.

The thin film transistors are formed on the glass substrate 8 and the glass substrate 8 is made of glass which is referred to as alkali-free glass. The glass substrate 8 contains so impurities, and there exists the possibility that the impurities will intrude into the polysilicon film 5 and deteriorate the

transistor characteristics of the thin film transistors formed on the substrate. To suppress the intrusion of the impurities from the glass substrate 8 to the polysilicon film 5, a background film made of silicon nitride, silicon oxide or the like is formed between the glass substrate 8 and the polysilicon film 5. The background film is formed over the whole surface of the panel, and the light transmissive pixel electrodes 3 and the common electrodes C are formed over the background film <sup>along with</sup> ~~besides~~ the thin film transistors.

A first background film 9 is formed over the substrate 8 over which the thin film transistors are formed, while a second background film 10 is formed over the first background film 9. Then, the polysilicon film 5 is formed over the second background film 2. The manner of forming these films, the constitution of and manner of forming the first interlayer insulation film and the second interlayer insulation film are <sup>the same as</sup> ~~equal to~~ those of the first embodiment.

<sup>which is</sup>  
An organic insulation film 18, <sup>which is</sup> formed over the second interlayer insulation film, is also referred to as a leveling film. By forming the organic insulation film 18, the surface on which the common electrodes C and the pixel electrodes 3 are formed constitutes a flat surface which is not influenced by surface irregularities of the second interlayer insulation film 16. By providing the organic insulation film 18, the coupling capacitance among wiring consisting of the gate lines, the drain

lines and the common lines can be reduced. Due to the reduction of the coupling capacitance, the power consumption of the liquid crystal display device can be reduced.

The common electrodes C and the pixel electrodes 3 are formed over the organic insulation film 18. The common electrodes C and the pixel electrodes 3 are formed within the pixel and are formed of a light transmissive film. For example, as the transparent electrode, ITO (Indium Tin Oxide) can be used.

Contact holes 15 are formed in the second interlayer insulation film 16 and the organic insulation film 18 so as to establish the ~~electric~~<sup>electrical</sup> connection between the source electrode S and the pixel electrode 3.

In this embodiment, the above-mentioned constitution is applied to the liquid crystal display device for <sup>a</sup> normally black display.

In the pixel portion, light transmissive films are stacked, and these stacked films differ in ~~the~~ refractive index from each other. To prevent the reflection of an external light from the counter substrate side, the film thicknesses of the light transmissive films are controlled.

Fig. 12 is a cross-sectional view taken along a line II-II in Fig. 10.

Due to the provision of the background films, the developing solution, the etchant, the resist removing liquid or the like is not brought into contact with the glass substrate



in the photolithography step, and hence, it is possible to suppress the dissolving of ions, such as sodium ions, from the glass substrate. If the dissolving of ions can be eliminated, it is possible to reuse these liquids again after filtering them, whereby it is possible to prevent the whole manufacturing line <sup>being subjected to</sup> from contamination. Further, the manufacturing cost can be reduced.

A gate insulation film 12, a first interlayer insulation film 13, a second interlayer insulation film 16, <sup>and</sup> an organic insulation film 18 are formed over the second background film in a stacked manner. Over the organic insulation film 18, the pixel electrodes 3 and the common electrodes C are formed on the same substrate. The orientation film 22 is formed over the glass substrate 8 such that the orientation film 22 covers the organic insulation film 18, the pixel electrodes 3 and the common electrodes C. The liquid crystal layer <sup>19</sup> is formed such that the layer is brought into contact with the orientation film 22.

These films are arranged within the pixel and have light transmissive characteristics. Particularly, since a given voltage is applied to the pixel electrodes and the common electrodes, these electrodes are formed of ITO (Indium Tin Oxide), which is a transparent conductive <sup>material</sup> ~~film~~. By controlling liquid crystal molecules in response to an electric field generated between the pixel electrode and the common electrode, <sup>the</sup> ~~a~~ light transmission quantity is controlled.

As an ideal, the liquid crystal display device is

constituted such that ~~the~~ following formula is satisfied, assuming, ~~that~~  
the film thickness ~~is~~ <sup>is</sup>  $d$ (nm) and ~~a~~ <sup>the</sup> refractive index ~~when~~ <sup>for</sup> a  
wavelength ~~is~~ <sup>of</sup>  $555\text{nm}$  ~~as~~ <sup>is</sup>  $n$  ( $m$  being an arbitrary integer excluding  
a negative integer).

$$d = 555 \times m / (2 \times n)$$

However, in ~~an~~ actual use, in view of ~~the~~ manufacturing  
error<sup>or</sup> the like, it is necessary to adjust the film thickness  
within about 10% of the film thickness in addition to the  
calculated value. It is preferable to control the film thickness  
within ~~the~~ <sup>an</sup> error of 10nm.

Within the pixel region, on the glass substrate 8, there  
are provided the second background film 10, the gate insulation  
film 12, the first interlayer insulation film 13 and the leveling  
film 18, which have a relatively low refractive index, and the  
first background film 9 and the second interlayer insulation  
film 16, ~~having~~ <sup>which have</sup> a relatively high refractive index.

The respective films having the relatively high refractive  
index are configured to ~~respectively~~ <sup>each</sup> satisfy ~~a~~ <sup>the</sup> following formula,  
assuming ~~the~~ <sup>that</sup> the film thickness ~~is~~ <sup>is</sup>  $d$ (nm) and ~~a~~ <sup>the</sup> refractive index ~~when~~ <sup>for</sup>  
a wavelength ~~is~~ <sup>of</sup>  $555\text{nm}$  ~~as~~ <sup>is</sup>  $n$  ( $m$  being an arbitrary integer excluding  
a negative integer).

$$0.9d \leq 555 \times m / (2 \times n) \leq 1.1d$$

Although the above range allows  $\pm 10\%$  of the film thickness  
as the range of error, when the film thickness  $d$  exceeds 200nm,  
 $\pm 15\%$  of the given film thickness is allowable as the range of

error. Due to such a constitution, it is possible to suppress the reflection of an external light attributed to the difference in refractive index when light passes from the film having the high refractive index to the film having the low refractive index, whereby ~~the~~ display of ~~the~~ <sup>an</sup> inverted image can be suppressed.

Further, the respective films having ~~the~~ <sup>a</sup> relatively low refractive index are configured to respectively satisfy ~~a~~ <sup>the</sup> following formula, assuming <sup>that</sup> the film thickness ~~as~~ <sup>is</sup>  $d$  (nm) and ~~a~~ <sup>the</sup> refractive index ~~when~~ <sup>for</sup> a wavelength ~~is~~ <sup>of</sup>  $555\text{nm}$  ~~as~~ <sup>is</sup>  $n$  ( $m$  being an arbitrary integer excluding a negative integer).

$$0.9d \leq 555 \times m / (2 \times n) \leq 1.1d$$

Although the above range allows  $\pm 10\%$  of the film thickness as the range of error, when the film thickness  $d$  exceeds  $200\text{nm}$ ,  $\pm 15\%$  of the given film thickness is allowable as the range of error. Due to such a constitution, it is possible to further suppress the reflection of ~~an~~ external light in the transmissive region, whereby ~~the~~ display of ~~the~~ <sup>an</sup> inverted image can be suppressed.

Fig. 13 shows a specific <sup>example</sup> ~~embodiment~~ of materials, thicknesses (film thicknesses) and the refractive indices of respective films or layers when the wavelength is  $555\text{nm}$ . In this <sup>case</sup> ~~embodiment~~, the gap  $L2$  of the transmissive region is set to  $5.2\mu\text{m}$ .

The first background film and the second background film differ in ~~the~~ refractive index. To protect the polysilicon film

from the impurities in the glass substrate, the first background film may preferably have a film thickness of at least 45nm. In this embodiment, the material of the first background film 9 is silicon nitride, the refractive index of the first background film 9 is 1.85, and the film thickness of the first background film 9 is 150nm. The material of the second background film 10 is silicon oxide, the refractive index of the second background film 10 is 1.5, and the film thickness of the second background film 10 is 100nm. The first background film is formed thicker than the second background film.

The material of the gate insulation film 12 is silicon oxide in the same manner as the second background film, while the refractive index of the gate insulation film 12 is 1.5 and the film thickness of the gate insulation film 12 is 100nm. The material of the first interlayer insulation film 13 is silicon oxide in the same manner as the second background film, while the refractive index of the first interlayer insulation film 13 is 1.5 and the film thickness of the first interlayer insulation film 13 is 540nm. With respect to the second interlayer insulation film 16, the material is silicon nitride, the refractive index is 1.85 and the film thickness is 300nm. With respect to the leveling film 18, an organic film having <sup>2</sup>~~the~~ refractive index of 1.6 is used and the film thickness is 1750nm. With respect to the pixel electrode 3 and the common electrode 6, these electrodes are made of ITO, the refractive index is

2.0 and the film thickness is 140nm. Further, the refractive indices of the orientation film 22 and the liquid crystal are 1.5.

Among these films, the second background film, which constitutes the liquid-crystal-layer-side background film, has the same refractive index as that of the gate insulation film and the first interlayer insulation film, and, hence, they can be considered as the same film. Accordingly, the first film is the silicon nitride film, which is constituted of the first background film, and, hence, the refractive index is 1.85 and the film thickness is 150nm. The second film is the silicon oxide film, which is constituted of the second background film, the gate insulation film and the first interlayer insulation film, and, hence, the refractive index is 1.5 and the film thickness is 740nm. Further, the third film is constituted of the second interlayer insulation film, the fourth film is constituted of the leveling film, and the fifth film is constituted of an ITO film.

The first and the fifth films satisfy <sup>the</sup> following formula, assuming <sup>that</sup> the film thickness <sup>is</sup>  $d$  (nm) and <sup>the</sup> refractive index <sup>when</sup>  $n$  at a wavelength <sup>of</sup> 555nm <sup>is</sup>  $n$  ( $m$  being an arbitrary integer excluding a negative integer).

$$d(1-0.1) \leq 555 \times m / (2 \times n) \leq d(1+0.1)$$

On the other hand, the second, the third and the fourth films satisfy <sup>the</sup> following formula, assuming <sup>that</sup> the film thickness

~~is~~ <sup>is</sup> ~~as~~ <sup>the</sup> ~~d~~ (nm) and ~~a~~ <sup>the</sup> refractive index ~~when~~ <sup>for</sup> a wavelength ~~is~~ <sup>of</sup> 555nm ~~as~~ <sup>is</sup>  
 $n$  ( $m$  being an arbitrary integer excluding a negative integer).

$$d (1 - 0.15) \leq 555 \times m / (2 \times n) \leq d (1 + 0.15)$$

Due to such a constitution, the reflection of ~~the~~ external light on respective kinds of films formed on the glass substrate 8 in the transmissive region can be suppressed, whereby it is possible to enhance the visibility of <sup>an</sup> image when the image is displayed by reflecting the external light at the backlight side of the panel. Particularly, the first background film is formed with <sup>a</sup> ~~the~~ large film thickness, and, hence, intrusion of ~~the~~ impurities into the polysilicon film from the substrate can be suppressed.

Fig. 14 and Fig. 15 are views showing the spectral luminous reflectance of the region in the pixel where the pixel electrode and the common electrode are not formed.

Fig. 14 is a view showing the spectral luminous reflectance when the first background film, the second background film, the gate insulation film, the first interlayer insulation film, the leveling film and the ITO film assume <sup>the</sup> values shown in Fig. 13, and the film thickness of the second interlayer insulation film is changed within a range of 100nm to 500nm. The spectral luminous reflectance is taken on an axis of ordinates and the film thickness of the second interlayer insulation film is taken on an axis of abscissas. The spectral luminous reflectance, when the film thickness of the second interlayer insulation film is

about 150nm, is about 0.45%, and, hence, the spectral luminous reflectance takes the lowest value. The spectral luminous reflectance assumes the low value next to the lowest when the film thickness of the second interlayer insulation film is about 300nm. That is, the spectral luminous reflectance is about 0.88%.

Fig. 15 is a view showing the spectral luminous reflectance when the second background film, the gate insulation film, the first interlayer insulation film, the second interlayer insulation film, the leveling film and the ITO film assume values shown in Fig. 13 and the film thickness of the first background film is changed within a range of 25nm to 350nm. The spectral luminous reflectance is taken on an axis of ordinates and the film thickness of the first interlayer insulation film is taken on an axis of abscissas. The spectral luminous reflectance, when the film thickness of the first background film is about 150nm, is about 0.88%, and, hence, the spectral luminous reflectance takes the lowest value. The spectral luminous reflectance assumes the low value next to the lowest when the film thickness of the first background film is about 300nm. That is, the spectral luminous reflectance is about 1.33%.

Fig. 16, Fig. 17 and Fig. 18 are views showing the spectral luminous reflectance of the region in the pixel where the pixel electrode and the common electrode are formed.

Fig. 16 is a view showing the spectral luminous reflectance

when the first background film, the second background film, the gate insulation film, the first interlayer insulation film, the second interlayer insulation film and the leveling film assume <sup>the</sup> values shown in Fig. 13 and the film thickness of the ITO film is changed within a range of 50nm to 300nm. The spectral luminous reflectance is taken on an axis of ordinates and the film thickness of the ITO film is taken on an axis of abscissas. As shown in Fig. 16, the spectral luminous reflectance, when the film thickness of the ITO film is about 140nm, is about 1.3%, and hence, the spectral luminous reflectance takes the lowest value. The spectral luminous reflectance assumes the low value next to the lowest when the film thickness of the ITO film is about 280nm. That is, the spectral luminous reflectance is about 2.1%.

Fig. 17 is a view showing the spectral luminous reflectance when the first background film, the second background film, the gate insulation film, the first interlayer insulation film, the leveling film and the ITO film assume <sup>the</sup> values shown in Fig. 13 and the film thickness of the second interlayer insulation film is changed within a range of 100nm to 400nm. The spectral luminous reflectance is taken on an axis of ordinates and the film thickness of the second interlayer insulation film is taken on an axis of abscissas. The spectral luminous reflectance, when the film thickness of the second interlayer insulation film is about 150nm, is about 1.02%, and hence, the spectral luminous reflectance takes the lowest value. The spectral luminous



reflectance assumes the low value next to the lowest when the film thickness of the second interlayer insulation film is about 300nm. That is, the spectral luminous reflectance is about 1.3%.

Fig. 18 is a view showing the spectral luminous reflectance when the second background film, the gate insulation film, the first interlayer insulation film, the second interlayer insulation film, the leveling film and the ITO film assume <sup>the</sup> values shown in Fig. 13 and the film thickness of the first background film is changed within a range of 50nm to 325nm. The spectral luminous reflectance is taken on an axis of ordinates and the film thickness of the first interlayer insulation film is taken on an axis of abscissas. The spectral luminous reflectance, when the film thickness of the first background film is about 150nm, is about 1.3%, and hence, the spectral luminous reflectance takes the lowest value. The spectral luminous reflectance assumes the low value next to the lowest when the film thickness of the first background film is about 300nm. That is, the spectral luminous reflectance is about 1.56%.

In this example, in addition to results shown in Fig. 14 and Fig. 17, from a viewpoint of reduction of capacitance and reduction of contamination attributed to the organic film, the film thickness of the second interlayer insulation film is set to 300nm and the film thickness of the first background film is set to 150nm in view of Fig. 15 and Fig. 18. Due to such a constitution, it is possible to suppress the interface reflection

which appears when light advances from ~~the~~<sup>19</sup> film having ~~the~~<sup>19</sup> relatively high refractive index to ~~the~~<sup>19</sup> film having ~~the~~<sup>19</sup> relatively low refractive index.

Fig. 19 is a view showing the relationship between ~~and~~<sup>the</sup> wavelength of light and ~~spectral~~<sup>the</sup> luminous reflectance when ~~a~~<sup>the</sup> thickness of the first background film is 75nm, and Fig. 20 is a graph showing the relationship between ~~a~~<sup>the</sup> wavelength of light and ~~spectral~~<sup>the</sup> luminous reflectance when ~~a~~<sup>the</sup> thickness of the first background film is 150nm. In Fig. 19 and Fig. 20, the reflectance (%), the spectral luminous reflectance (%) and visibility are taken on the axis of ordinates and the wavelength (nm) of light is taken on an axis of abscissas. Here, the visibility is set to 1 when the wavelength is 555nm, which gives the strongest visibility to ~~human~~<sup>the eye</sup>. In Fig. 19, the visibility is about 0.028 when the wavelength is 555nm.

On the other hand, in Fig. 20, the visibility when the wavelength is 555nm is about 0.0009, and, hence, the reflection light having the wavelength of 555nm can be suppressed to an extent that ~~human~~<sup>the eye</sup> can hardly recognize the reflection light. ~~human~~<sup>the eye</sup> is most sensitive to light having ~~the~~<sup>a</sup> wavelength of 555nm, and, hence, the contrast can be enhanced by suppressing the reflection of light having ~~the~~<sup>a</sup> wavelength in the vicinity of 555nm.

The reflective light from the multilayered film is generated such that, since the refractive indices of the

respective layers which constitute the multilayered film are different from each other, interface reflections occur between respective layers, and these interface reflections interfere with each other, thus generating the reflection light.

Fig. 21 is a plan view <sup>as seen</sup> when the second substrate 7 on which color filters are formed is overlapped to the first substrate 4. Particularly, Fig. 21 is a view which <sup>illustrates</sup> ~~explains~~ the positional relationship between the positions of the drain lines and gate lines formed on the first substrate with the position of the black matrixes BM formed on the second substrate. The color filters and the black matrixes BM are formed on the second substrate 7.

~~In~~ the full transmissive type liquid crystal display device, <sup>is reflected</sup> ~~reflects~~ the external light by the drain lines and the gate lines which are formed of a metal thin film, and, hence, the contrast of <sup>the</sup> ~~images~~ is degraded. Accordingly, the black matrixes BM are arranged to overlap the drain lines and the gate lines. Due to such an arrangement of the black matrixes BM, the degradation of the contrast of images can be suppressed.

Fig. 22 ~~is a view for explaining the third embodiment and~~ <sup>according to a third embodiment,</sup> is a plan view of a liquid crystal display device, in which a substrate on which pixel electrodes are formed and a substrate on which common electrodes are formed are arranged to face each other in an opposed manner with a liquid crystal layer <sup>disposed</sup> therebetween. To parts shown in Fig. 22 which have the identical

functions as those of the first embodiment, the same reference symbols are given. Further, the embodiment shown in Fig. 22 is applied to a full transmissive type display device, which includes no reflective electrodes for displaying images by reflecting an external light on pixel portions.

Hereinafter, the point which makes this embodiment different from the second embodiment ~~is~~ <sup>will be</sup> explained in detail.

The thin film transistors and the pixel electrodes 3 are formed on one of ~~the~~ <sup>two</sup> substrates which face each other in an opposed manner with the liquid crystal layer ~~therebetween~~ <sup>disposed</sup>. In each pixel portion, in the same manner as the first embodiment, gate electrodes G, drain electrodes D, source electrodes S, gate lines 1, drain lines 2, the pixel electrodes 3, a polysilicon film 5, a contact hole 14 for forming a thin film transistor TFT, ~~and~~ <sup>and</sup> contact holes 15 are formed. The constitution which makes this embodiment largely different from the first embodiment lies in ~~a point~~ <sup>the fact</sup> that common electrodes are not formed on the same layer as the pixel electrodes 3 and ~~a point~~ <sup>the fact</sup> that storage lines (storage electrodes) 6 are formed on the same layer as the gate lines. By providing ~~the~~ <sup>these</sup> storage lines, the holding capacitance of the pixel electrodes can be increased.

Fig. 23 is a plan view of black matrixes BM which are formed on the second substrate 7 (color filter substrate). The black matrixes BM are arranged such that the black matrixes BM cover the gate electrodes G, the drain electrodes D, the source

electrodes S, the gate lines 1, the drain lines 2 and the storage lines 6, all of which constitute metal portions in Fig. <sup>22</sup>~~11~~. By arranging the black matrixes BM in such a manner, the reflection of the external light by the metal portions can be prevented, and, hence, the contrast can be enhanced. Further, the counter electrodes (common electrodes) C are formed on a surface of the second substrate 7 which faces the liquid crystal layer. An orientation film is formed over the second substrate 7 such that the orientation film also covers the counter electrodes C.

Fig. 24 is a cross-sectional view taken along a line III-III in Fig. 22.

The first background film 9 <sup>and</sup> the second background film 10 are formed over the glass substrate 8, and the polysilicon film 5 is formed on the second background film 10. The gate insulation film 12 is formed so as to cover the polysilicon film 5, and the gate electrodes G are formed on the gate insulation film. Further, the storage electrodes 6, which are formed on the same layer as the gate electrodes G, are formed over the gate insulation film 12. The first interlayer insulation film 13 is formed such that the first interlayer insulation film 13 covers the gate electrodes G, the storage electrodes 6 and the gate insulation film. The contact holes 14 are formed in portions of the first interlayer insulation film 13 and the gate insulation film so that respective connections between the polysilicon film 5 and gate electrodes G and between the polysilicon film 5 and

the source electrodes S can be established. The drain electrodes D and the source electrodes S, which are formed on the first interlayer insulation film, have a three-layered structure consisting of a titanium-tungsten layer as a lower layer, an aluminum layer as an intermediate layer and a titanium-tungsten layer as an upper layer. In Fig. 24, the lower layer and the intermediate layer are shown as one film. The titanium-tungsten layer constituting the upper layer ensures the electrical connection with the pixel electrodes 3. The second interlayer insulation film 16 is formed such that the insulation film 16 covers the drain electrodes, the source electrodes and the first interlayer insulation film, while the organic insulation film 18 is formed such that the insulation film 18 covers the second interlayer insulation film. Contact holes 15 are formed in portions of the organic insulation film, and this enables the connection between the source electrodes and the pixel electrodes. ITO (Indium Tin Oxide) is used as a material of the pixel electrodes. An orientation film 22 is formed over a surface of the first substrate over which these layers are respectively formed and which faces the liquid crystal layer 19.

On the pixel region, the light transmissive films are laminated and these laminated films have different refractive indices. To prevent the reflection of the external light from the counter substrate side, the film thicknesses of the light transmissive films are controlled.

Also, in the third embodiment, the film thicknesses are configured to respectively satisfy <sup>the</sup> following formula, assuming <sup>that</sup> the film thickness of each film <sup>is</sup>  $d$  (nm) and the refractive index <sup>for</sup>  $n$  when <sup>of</sup> the wavelength <sup>is</sup> 555nm ( $m$  being an arbitrary integer excluding a negative integer) <sup>is</sup>  $n$ .

$$d = 555 \times m / (2 \times n).$$

Further, considering ~~the~~ manufacturing errors, the visibility or the like, it is necessary to reduce or add the thickness of approximately 10% of the film thickness in addition to the calculated value. The film thickness is favorably controlled within <sup>an</sup> ~~the~~ error of 10nm.

That is, the film thicknesses are configured to respectively satisfy <sup>the</sup> following formula, assuming <sup>that</sup> the film thickness of each film <sup>is</sup>  $d$  (nm) and the refractive index <sup>for</sup>  $n$  when <sup>of</sup> the wavelength <sup>is</sup> 555nm ( $m$  being an arbitrary integer excluding a negative integer) <sup>is</sup>  $n$ .

$$0.9d \leq 555 \times m / (2 \times n) \leq 1.1d.$$

Further, in view of the allowable range of the visibility, when the film thickness  $d$  exceeds ~~the~~ 200nm,  $\pm 15\%$  of the given film thickness is allowable.

That is, the film thicknesses are configured to respectively satisfy <sup>the</sup> following formula, assuming <sup>that</sup> the film thickness of each film <sup>is</sup>  $d$  (nm) and the refractive index <sup>for</sup>  $n$  when <sup>of</sup> the wavelength <sup>is</sup> 555nm ( $m$  being an arbitrary integer excluding a negative integer) <sup>is</sup>  $n$ .

$$0.85d \leq 555 \times m / (2 \times n) \leq 1.15d.$$

The specific thickness is shown in Fig. 13.

By constituting the laminated film structure in this manner, the reflection of ~~the~~ external light attributed to the difference of the refractive index when the light passes from the film having <sup>a</sup>~~the~~ high refractive index to the film having <sup>a</sup>~~the~~ low refractive index can be suppressed, and ~~the~~ display of <sup>an</sup>~~the~~ inverted image can be suppressed.

Fig. 25 is a cross-sectional view of the liquid crystal display device, <sup>illustrating</sup>~~for explaining~~ the arrangement of a backlight structural body which is used in common by the embodiments of the present invention.

The first substrate 4 and the second substrate 7 are arranged to face each other in an opposed manner while sandwiching the liquid crystal layer 19 therebetween. The first substrate and the second substrate are fixed by a sealing material 11.

The polarizer 20 is arranged on the image display surface side (image observing surface side) of the second substrate, and the polarizer 21 is also arranged on the backlight side (opposite to the image observing surface side) of the first substrate. Further, a light diffusion layer 17 is disposed between the first substrate 7 and the polarizer 21. Further, a reflection polarizer 23 is arranged on the backlight side of the polarizer 21.

The backlight structural body is constituted of at least



a light guide plate 25, a light source 26 and a reflection plate 27. A light diffusion sheet 24 may be arranged on the front surface of the light guide plate 25 when necessary.

The light diffusion layer 17 is made of a diffusion tacky adhesive material. The diffusion tacky adhesive material has both ~~the~~ a light diffusion function and a function of fixing the polarizer and the first substrate. Further, the light diffusion sheet 24 is arranged in front of the polarizer (observing window side) so as to diffuse light.

The light 28 incident from the observing window to the panel is diffused by the light diffusion layer 17 and the light diffusion sheet 24 and reaches the reflection plate 27. The reflected light 29 is also irradiated from the panel after passing through the diffusion sheet and the light diffusion layer 17, and, hence, the light is sufficiently diffused whereby the luminance mottling can be suppressed. Further, the occurrence of a shadow of the image which is generated when the image is observed in an oblique direction can be prevented, and, hence, the image recognition is improved. Particularly, the lateral field type liquid crystal display device has a wide viewing angle, and, hence, the present invention is preferably applicable to such a display device. Further, with the provision of the reflection polarizer 23, the external light can be effectively used.

On the other hand, the light 30 irradiated from the light

source 26 of the backlight passes through the light guide plate 25 and is bent toward the image display surface side. The light 30 is also diffused by the light diffusion sheet and the light diffusion layer, and hence, ~~the~~ luminance mottling on the image display surface can be suppressed. With such a constitution, when the ~~using~~<sup>surrounding</sup> environment is dark, the image is displayed using ~~the~~ light from the backlight, and when the ~~using~~ environment is bright, the image is displayed by reflecting the external light. Particularly, the inverted display of the image, which may occur when the image is displayed by reflecting the external light, can be suppressed.

Further, it is also possible to use both ~~the~~ the external light and the backlight. In this case, even when the ~~using~~<sup>surrounding</sup> environment is bright, ~~the~~<sup>an</sup> image display having a favorable contrast can be ~~displayed~~<sup>produced</sup>.

Further, ~~although~~ in the above-mentioned embodiments, ~~the~~<sup>although</sup> the first substrate 4 is ~~explained~~<sup>described</sup> as ~~the~~<sup>a</sup> glass substrate, a similar drawback arises so long as the substrate needs ~~the~~<sup>a</sup> background film. The first substrate may be formed of a substrate other than ~~the~~<sup>a</sup> glass substrate. Further, even other than the background film, by applying the above-mentioned constitution to ~~the~~<sup>a</sup> structure which is formed by forming the multilayered film in the light transmissive portion, the image recognition can be improved.

In the application which constitutes a basis for claiming

the internal priority with respect to the present application, the film thickness of the nitride silicon is defined as

$$d \pm 10 = 555 \times m / 2 \times n.$$

← However, in this previous domestic application, as clearly shown in Fig. 5, Fig. 6 and Fig. 7, it is found that when the film thickness of the background film is set to 140nm, the spectral luminous reflectance becomes minimum. That is, the previous domestic application ~~describes that assuming~~ <sup>is based on the assumption that, when</sup> the film thickness of the background film ~~is~~ <sup>is</sup>  $d(\text{nm})$  and the refractive index ~~when~~ <sup>for</sup> ~~the~~ <sup>the</sup> wavelength is  $555\text{nm}$ , ~~as~~ <sup>is</sup>  $n$ , a following formula is satisfied.

$$d = 555 \times m / 2 \times n$$

Further, the previous domestic application also ~~describes~~ <sup>indicates</sup> that it is necessary to adjust the film thickness of the background film ~~within~~ <sup>to</sup> approximately 10% of the film thickness considering manufacturing error, and the film thickness is favorably controlled with ~~the~~ <sup>an</sup> allowable error of 10nm. That is, according to the technical concept of the present invention, it is a requisite that, ~~assuming~~ <sup>that</sup> the film thickness of the background film ~~is~~ <sup>is</sup>  $d(\text{nm})$  and the refractive index ~~when~~ <sup>for</sup> ~~the~~ <sup>the</sup> wavelength is  $555\text{nm}$ , ~~as~~ <sup>is</sup>  $n$ , ~~a~~ <sup>the</sup> following formula is satisfied.

$$d - 10 \leq 555 \times m / (2 \times n) \leq d + 10$$

← However, in the specification of the previous domestic application, there existed some deficiencies in the description of ~~the~~ <sup>the</sup> formula.

In the display device of the present invention, it is

preferable to set the film thickness of the nitride silicon of the background film within a range of  $140\text{nm} \pm 10\text{nm}$  (within a range of 130nm to 150nm) which provides the minimum spectral luminous reflectance. However, this range is a value which is obtained when the refractive index of the nitride silicon is set to 2.0 and the refractive index of the nitride silicon varies within a range of 2.0 to 1.85. When the refractive index is set to 1.85, it is preferable to set the film thickness within a range of  $150\text{nm} \pm 10\text{nm}$  (within a range of 140nm to 160nm). Accordingly, by taking the change of the refractive index of the nitride silicon into consideration, it is preferable that the film thickness of the nitride silicon of the background film is set within a range of 130nm to 160nm.

Further, in the specification of the previous domestic application, it is ~~described~~<sup>indicated</sup> that it is necessary to increase or decrease the film thickness of the nitride silicon of the background film within 10% of the thickness by taking ~~the~~ manufacturing error into consideration. Under such a condition, when the refractive index of the nitride silicon of the background film is 2.0, it is necessary to adjust the film thickness within a range of  $140\text{nm} \pm 14\text{nm}$ , that is, within a range of 126nm to 154nm. Further, when the refractive index of the nitride silicon of the background film is 1.85, it is necessary to adjust the film thickness within a range of  $150\text{nm} \pm 15\text{nm}$ , that is, within a range of 135nm to 165nm. Accordingly, by taking the change

of the refractive index of the nitride silicon into consideration, it is necessary to adjust the film thickness of the nitride silicon of the background film within a range of 126nm to 165nm. Further, there may be a case <sup>in which</sup> ~~that~~ the film thickness of the nitride silicon changes within approximately 15% depending on <sup>the</sup> ~~a~~ manufacturing device or <sup>being employed</sup> ~~a~~ manufacturing process. In such a case, it is necessary to set the film thickness of the nitride silicon of the background film in a range of about 120nm to 170nm. Even within this range, it is possible to decrease the reflection of the nitride silicon compared to the conventional technique. Further, as mentioned above, to protect the polysilicon film from the impurities of the substrate, it is sufficient that the film thickness of the nitride silicon which constitutes the first background film is set to a value equal to or more than 45nm. The film thickness of the nitride silicon background film shown in Fig. 4 within a range of 50nm to 180nm is a range determined by focusing on the advantageous effect of reducing the intrusion of the impurities from the substrate. Accordingly, to increase this advantageous effect in decreasing the reflection of the nitride silicon film further, it is favorable to restrict the film thickness in a narrower range.

Here, the relationship between the film thickness of the background nitride silicon film and the spectral luminous reflectance shown in Fig. 5 is obtained by setting the refractive index of the nitride silicon film to about 2 (roughly 1.98).

Fig. 5 also shows a case in which the refractive index is set to 1.85. However, the refractive index of the nitride silicon film changes from 1.8 to 2.1 according to the properties of the manufacturing device or the manufacturing <sup>being employed</sup> process. Accordingly, by setting the film thickness to 132nm when the refractive index of the nitride silicon is 2.1 and by setting the film thickness to 154 nm when the refractive index is 1.8, the spectral luminous reflectance assumes the minimum value. That is, ~~to take~~ <sup>taking</sup> the change of the refractive index of the nitride silicon film of the background film into consideration, by setting the film thickness of the nitride silicon of the background film within a range of 132nm to 154nm, the spectral luminous reflectance can be suppressed to a low value.

Here, considering that the refractive index of the background film changes from 1.8 to 2.1, when the film thickness is adjusted within a range of 10nm, as mentioned above, it is favorable to set the film thickness to a value which falls within a range of 122nm to 164nm. Further, when the film thickness of the nitride silicon of the background film is adjusted within a range of 10% of the thickness, it is necessary to adjust the film thickness of the nitride silicon of the background film in a range of 118nm to 169nm.

The restriction of the film thickness of the nitride silicon background film described here relates to the film thickness of the transmissive portion within the pixel region.

Although ~~the~~ values of the film thickness have been described heretofore, it is preferable to set these values as follows. That is, assuming ~~that~~ <sup>is</sup> the film thickness of the background film of the nitride silicon ~~as~~ <sup>is</sup>  $d$ (nm) and the refractive index ~~when the wavelength is~~ <sup>for a</sup>  $555\text{nm}$  ~~as~~ <sup>of</sup>  $n$ , it is favorable to set the film thickness such that a following formula is satisfied

$$d - 10 \leq 555 \times m / (2 \times n) \leq d + 10$$

~~to~~ when the film thickness is suppressed within a range of  $\pm 10\text{nm}$ , and

$$d \times (1 - 0.01 \times a) \leq 555 \times m / (2 \times n) \leq d + (1 + 0.01 \times a)$$

when the film thickness is suppressed in a range of  $\pm a\%$ .

According to the present invention, by reducing the reflection of light from the transmissive region, a contrast which is formed by the reflective pixel electrode, the liquid crystal layer arranged above the reflective pixel electrode, the optical retardation plate, ~~and~~ <sup>and</sup> the polarizer can be enhanced. Further, the present invention also provides ~~the~~ <sup>a</sup> display device ~~which can enhance the~~ <sup>exhibiting an enhanced</sup> visibility of images when the images are displayed by reflecting ~~the~~ external light on the back surface side ~~than~~ <sup>of</sup> the first substrate. Still further, it is possible to enhance the visibility of images even when the reflective light and the light from the backlight are used simultaneously.